Standard Method of Test for

Direct Shear Test of Soils under Consolidated Drained Conditions

AASHTO Designation: T 236-22[1]

Technically Revised: 2022

Technical Subcommittee: 1a, Soil and Unbound Recycled Materials

ASTM Designation: D3080-72(2003)

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1. SCOPE

1.1. This method describes procedures for determining the consolidated drained shear strength of a soil material in direct shear. The test may be conducted in either a single shear or in a double shear, as shown in Figure 1. The direct shear test is well suited to a consolidated drained test because the drainage paths through the test specimen are short, thereby allowing excess pore pressures to be dissipated fairly rapidly. The test can be made on all soil material,[2] and on undisturbed or remolded samples.

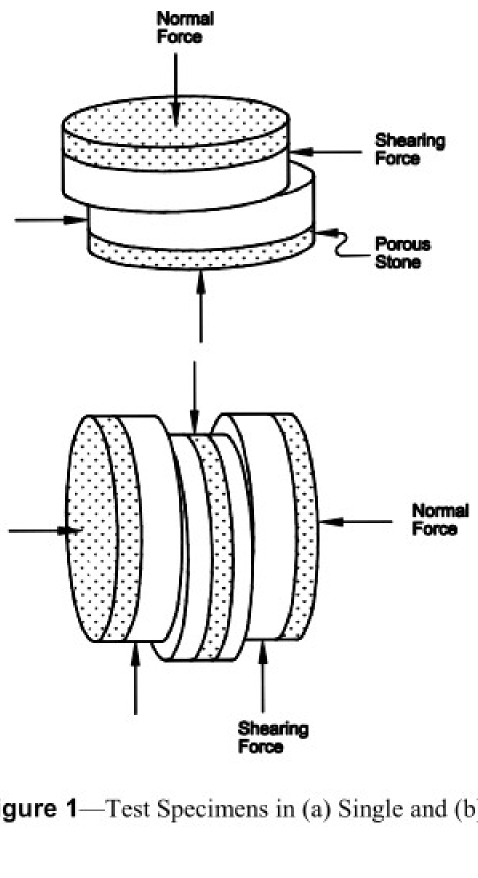

Figure 1—Test Specimens in (a) Single and (b) Double Shear

1.2. The test results are applicable to field situations where complete consolidation has occurred under the existing overburden and failure is reached slowly so that excess pore pressures are dissipated. The test is also useful in determining the shearing resistance along recognizable weak planes within the soil material.

Note 1—If failure is forced to occur on or near a horizontal plane at the middle of the specimen, it may not necessarily occur along the weakest plane, thereby overestimating shear strength parameters. Only when weak plane(s) are recognizable within the soil mass or interfaces between dissimilar materials are being tested, and the plane or interface at question is placed within the limits of the forced failure zone, can the shear resistance along these planes or interfaces be evaluated. The usefulness of direct shear test results was discussed in the Symposium on Direct Shear Testing of Soils; the proceedings appear in ASTM Special Technical Publication 131.

1.3. The test is not suited to the development of exact stress–strain relationships nor for evaluating any other associated quantities such as moduli within the test specimen because of the non-uniform distribution of shearing stresses and displacements. The slow rate of displacement provides for dissipation of excess pore pressures, but it also permits plastic flow of soft cohesive soils. Care should be taken that the testing conditions represent those being investigated.

1.4. The values stated in SI units are to be regarded as the standard.

1.5. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENT

2.1. *AASHTO Standards*:

- M 339M/M 339, Thermometers Used in the Testing of Construction Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- T 265, Laboratory Determination of Moisture Content of Soils

2.2. *ASTM Standards*:

- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E230/E230M, Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples
- E2877, Standard Guide for Digital Contact Thermometers

2.3. *International Electrotechnical Commission Standard*:

- IEC 60584-1: 2013 Thermocouples - Part 1: EMF Specifications and Tolerances

3. SUMMARY OF METHOD

3.1. The method consists of (a) placing the test specimen in the direct shear device, (b) applying a predetermined normal stress, (c) providing for drainage or wetting of the test specimen, (d) consolidating the specimen under the normal stress, (e) unlocking the frames that hold the test specimen, and (f) applying a shearing force to shear the specimen (Figures 1 and 2). Generally, three or more specimens are tested, each under a different normal stress to determine the effects on shear resistance and displacement. The range in normal stresses should be appropriate for the soil conditions being investigated.

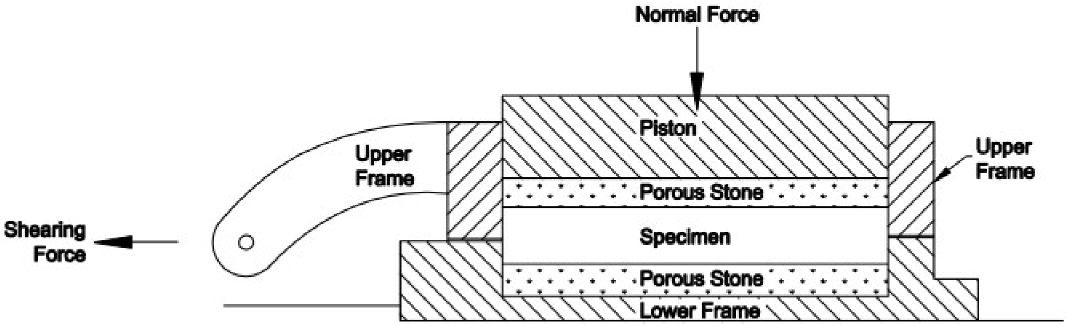

Figure 2—Typical Direct Shear Box for Single Shear

4. APPARATUS

4.1. *Shear Device*—A device (square or circular) to hold the specimen securely between two porous stones in such a way that torque cannot be applied to the specimen. The shear device shall provide means for applying a normal stress to the faces of the specimen, for measuring change in thickness of the specimen, for permitting drainage of water through the porous stones, and for submerging the specimen in water. The device shall be capable of applying a shearing force to shear the specimen along a predetermined shear plane (single shear) or shear planes (double shear) parallel to the faces of the specimen. The frames that hold the specimen shall be sufficiently rigid to prevent their distortion during shearing. The various parts of the shear device shall be made of material not subject to corrosion by substances within the soil or soil moisture.

4.2. *Porous Stones*—The porous stones shall consist of silicon carbide, aluminum oxide, or metal that is not susceptible to corrosion by soil substances or soil moisture. The proper grade of stone depends on the soil being tested. The stone should be coarse enough to develop adequate interlock with the specimen and fine enough to prevent excessive intrusion of the soil into the pores. Exact criteria for this have not been established. For normal soil testing, medium grade stones with a permeability of about 0.5 to 1 mm/s are appropriate.

4.3. *Loading Devices*:

4.3.1. Device for applying the normal force shall be capable of applying the specified force quickly, without exceeding it, and capable of maintaining it with an accuracy of ±1 percent for the duration of the test.

4.3.2. Device for applying the shear force. The capabilities will depend on whether a controlled-displacement test or controlled-stress test is used. The former is generally preferred because the ultimate stress as well as the maximum stress can be determined. Controlled displacement equipment shall be capable of shearing the specimen at a uniform rate of displacement, with less than ±5 percent deviation, and should permit adjustment of the rate of displacement over a relatively wide range. The rate depends on the consolidation characteristics of the soils.[3] The rate is usually maintained with a motor and gear box arrangement and the shear force is determined by a force indicating device such as a proving ring. Controlled-stress equipment, if used, should be capable of applying the shear force in increments to the specimen in the same manner and to the same degree of accuracy as that described under Section 4.3.1.

4.4. *Calibration Disk*—The calibration disk should be a copper, aluminum, or hard steel disk of approximately the same height as the test specimen and at least 1 mm (0.04 in.) but no more than 5 mm (0.20 in.) smaller in diameter than the ring.

4.5. *Moisture Room*—For storing samples as well as for preparing samples where moisture loss during preparation does not exceed 0.5 percent.

4.6. *Trimmer or Cutting Ring*—For trimming oversized samples to the inside dimensions of the shear box with a minimum of disturbance. An exterior jig may be needed to maintain the succession of rings—two or three—in axial alignment.

4.7. *Balance*—Sensitive to 0.1 g or to 0.1 percent of the specimen mass.

4.8. *Displacement Indicators*—To measure change in thickness of the test specimen, with a sensitivity to 0.002 mm (0.0001 in.), and to measure horizontal displacement with a sensitivity of 0.02 mm (0.001 in.).

4.9. *Drying Oven*—That can be maintained at 110 ± 5°C (230 ± 9°F). Oven(s) for heating and drying shall be capable of operation at the temperatures required, between 100 to 120°C (212 to 248°F), within ±5°C (±9°F), as corrected, if necessary, by standardization. More than one oven may be used, provided each is used within its proper operating temperature range. The thermometer used for monitoring the temperature of the oven, or for measuring the temperature of materials shall meet the requirements of M 339M/M 339 with a temperature range of at least 90 to 130°C (194 to 266°F), and an accuracy of ±1.25°C (±2.25°F) (see Note 2).

Note 2—Thermometer types suitable for use include ASTM E1 mercury thermometers; ASTM E2877 digital metal stem thermometer; ASTM E230/E230M thermocouple thermometer, Type J or K, Special Class, Type T any Class; IEC 60584 thermocouple thermometer, Type J or K, Class 1, Type T any Class; or dial gauge metal stem (bi-metal) thermometer.

4.10. *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

4.11. *Equipment for Remolding or Compacting Specimens.*

4.12. *Miscellaneous Equipment*—Including a timing device with a second hand, distilled or demineralized water, spatulas, knives, straightedge, wire saws, etc., used in preparing the sample.

5. CALIBRATION

5.1. The calibration step is necessary in order to determine the deformation of the testing device when subjected to consolidation load. For each consolidation step, the corresponding device deformation will be subtracted from the observed deformation so that only deformations due to sample consolidation will be reported at the end of each consolidation step. Calibration of the testing device must be performed when the device is originally placed in service as well as whenever any of its components are changed. An annual calibration, at a minimum, should be performed.

5.2. Assemble the single shear direct shear device with the calibration disk used in place of the test specimen. The calibration disk should be a copper or hard steel disk of approximately the same height as the test specimen and at least 1 mm (0.04 in.) but no more than 5 mm (0.20 in.) smaller in diameter than the ring.

Note 3—The double shear device will require two calibration disks.

5.3. Position and adjust the normal displacement indicator so it can be used to measure either consolidation or swell from the "calibration disk" reading. Record the zero or "no load" reading.

5.4. Apply increments of normal force up to the equipment limitations and record both the applied normal force and the normal displacement indicator reading for future reference in determining the thickness of the test specimen and compression within the test apparatus itself. Remove the applied normal force in reverse sequence of the applied force and again record the normal displacement indicator readings and normal force. Calculate the average of the two recorded deformation values corresponding to each value of applied normal loading sequences (loading and unloading). Plot the average deformation of the device as a function of the applied load. As indicated in Section 4.1, this information will be used in determining the thickness of the test specimen and its compression within the testing device at the end of each consolidation loading step.

5.5. Remove the calibration disk.

Note 4—Other equally accurate methods for calibrating the apparatus are acceptable.

6. SAMPLE PREPARATION

6.1. If an undisturbed sample is used, it should be large enough to provide a minimum of three similar specimens. Prepare the specimens so that moisture loss is negligible. Trim oversized specimens to the inside diameter of the direct shear device and to the length of the trimmer. Extreme care shall be taken in preparing undisturbed specimens of sensitive soils to prevent disturbance of their natural structure. Determine the initial mass of the specimen for subsequent use in determining initial moisture content.

6.2. If specimens of compacted soil are used, they shall be compacted to the moisture content and unit weight as prescribed in the test request. They may be compacted directly in the shear device, in a mold of equal dimensions and extruded into the shear device, or in a larger mold and trimmed as in Section 6.1.

6.3. Minimum specimen diameter for circular specimens, or width of rectangular (square) specimens, shall be approximately 50 mm (2.00 in.). For undisturbed samples, the diameter of the sampling tube shall be greater than the specimen diameter to reduce disturbance in the specimen and prevent lateral displacement (Note 5).

Note 5—The diameter of undisturbed test specimens cut from tube samples should be at least 6 mm (0.25 in.) less than the diameter of the sampling tube to minimize disturbance caused by sampling.

6.4. Minimum specimen thickness shall be approximately 13 mm (0.5 in.), but not less than six times the maximum grain diameter.

6.5. Minimum specimen diameter-to-thickness ratio shall be 2:1. For square or rectangular specimens, the minimum width-to-thickness ratio shall also be 2:1.

7. PROCEDURE

7.1. Assemble the shear box with the frames aligned and locked in position.

A light coating of grease between the frames may be used to ensure watertightness during consolidation and reduce friction during shear.

Tetrafluoroethylene-fluorocarbon spacers or TFE-fluorocarbon-coated surfaces may also be used to reduce friction during shear. Carefully insert the test specimen. Connect the loading devices.

Position and/or activate the displacement indicators for measuring shear deformation and changes in specimen thickness. Determine the initial thickness of the specimen.

Note 6—The decision to dampen the porous stones before insertion of the specimen and before application of the normal force depends on the problem under study. For undisturbed samples from below the water table, the porous stones are usually dampened. For swelling soils, wetting should probably follow application of the normal force to prevent swell not representative of field conditions.

7.2. Consolidate each test specimen under the appropriate normal force. As soon as possible after applying the initial normal force, fill the water reservoir to a point above the top of the specimen. Maintain this water level during the consolidation and subsequent shear phases so that the specimen is at all times effectively submerged. Allow the specimen to drain and consolidate under the desired normal force or increments thereof prior to shearing. During the consolidation process, record the normal displacement readings before each increment of normal force is applied and at appropriate times.[4] Plot the normal displacement readings against elapsed time. Allow each increment of normal force to remain until primary consolidation is complete. The final increment should equal the previous normal force developed and should produce the specified normal stress.

Note 7—The normal force used for each of the three or more specimens will depend on the information required. Application of the normal force in one increment may be appropriate for relatively firm soils. For relatively soft soils, however, several increments may be necessary to prevent damage to the specimen. The initial increment will depend on the strength and sensitivity of the soil. This force should not be so large as to squeeze the soil out of the device.

7.3. *Shear the Specimen*—After consolidation is complete, unlock the frames and separate them slightly (0.64 mm [0.025 in.]) so the specimen can be sheared. Apply the shearing force and shear the specimen slowly to ensure complete dissipation of excess pore pressure. The following guide for total elapsed time to failure (t_f) may be useful in determining rate of loading:

$$t_f = 50\, t_{50}$$

where:

t_{50} = time required for the specimen to achieve 50 percent consolidation under the normal force.

Note 8—If the normal displacement versus square root of time is used, t_{50} can be calculated from the time to complete 90 percent consolidation using the following expression:

$$t_{50} = \frac{t_{90}}{4.28}$$

where:

t_{90} = time required for the specimen to achieve 90 percent consolidation under the specified normal force; and

4.28 = constant, relates displacement and time factors at 50 and 90 percent consolidation.

Note 9—If the material exhibits a tendency to swell, the soil must be saturated with water and must be permitted to achieve equilibrium under an increment of normal stress large enough to counteract the swell tendency before the minimum time to failure can be determined. The time-consolidation curve for subsequent normal stress increments is then valid for use in determining t_f.

Note 10—Some soils, such as dense sands and overconsolidated clays, may not exhibit well-defined time-settlement curves. Consequently, the calculation of t_f may produce an inappropriate estimate of the time required to fail the specimen under drained conditions. For overconsolidated clays that are tested under normal stresses less than the soil's preconsolidation pressure, it is suggested that a time to failure be estimated using a value of t_{50} equivalent to one obtained from normal consolidation time-settlement behavior. For clean, dense sands that drain quickly, a value of 10 min may be used for t_f. For dense sands with more than 5 percent fines, a value of 60 min may be used for t_f. If an alternative value of t_f is selected, the rationale for the selection shall be explained with the test results.

Note 11—The screws used for separating the frames should be retracted so they are not in contact with the lower frame before the shear force is applied. Also remove the pins or screws used for locking the frames together.

Note 12—In a controlled-displacement test, the rate of displacement (d_r mm/min or in./min) may be determined approximately by dividing the estimated shear (lateral) deformation (d_f mm or in.) at maximum shear stress by the computed time to failure (t_f):

$$d_r = \frac{d_f}{t_f}$$

The magnitude of the estimated shear (lateral) displacement at failure is dependent on many factors, among them the type and the stress history of the soil. As a guide, use $d_f = 12$ mm (0.5 in.) if the material is normally or lightly overconsolidated fine-grained soil, otherwise use $d_f = 5$ mm (0.2 in.).

7.3.1. Compute the percent relative shear (lateral) displacement for each shear force reading.

7.3.2. Continue the test until the shear stress becomes essentially constant or until a shear deformation of 10 percent of original diameter has been reached. In a controlled-stress test, begin with shearing force increments equal to about 10 percent of the estimated maximum. Permit at least 95 percent consolidation before applying the next increment. When 50 to 70 percent of the estimated failure force has been applied to the specimen, reduce the increment to one-half the initial size or 5 percent of the estimated maximum shear stress. As failure is approached, use a series of increments equal to one-fourth the initial increment. Record the applied shear force and the shear and normal deformations at convenient intervals. A continuous buildup of shearing force would be preferable.

7.4. At the completion of the test, remove the entire specimen from the shear box, oven-dry it in accordance with T 265, Laboratory Determination of Moisture Content of Soils, and weigh it to determine the mass of solids.

8. CALCULATIONS

8.1. Measure initial moisture content, specific gravity, mass, and volume of the total specimen.

8.2. Based on these measured quantities, compute initial void ratio, wet and dry densities, and initial degree of saturation of the sample.

8.3. Calculate shear stress data (maximum shear stress, normal stress at failure, actual displacement rates, etc.).

8.4. Void ratio after consolidation, as well as after the shear test, is desirable.

8.5. Final degree of saturation.

9. REPORT

9.1. Description of type of shear device used in the test and components serial or lab numbers, if available. List also the PIN (Project Identification Number) and its exact location (county and municipality, route number, and mile marker).

9.2. Identification and description of sample, including tube or jar number, depth of retrieval, whether soil is undisturbed, remolded, compacted, or otherwise prepared, and noting any unusual features such as stratification and soil structure.

9.3. Initial moisture content and degree of saturation.

9.4. Dry mass (mass of solids), initial wet and dry density.

9.5. Initial sample dimensions (thickness, width, length, diameter, etc.).

9.6. All basic test data including normal stress, shear displacements and corresponding shear resistance values, specimen thickness changes, and specimen final dimensions. Include Atterberg limits and grain size data, if available.

9.7. Plot of maximum shear stress versus normal stress. For each test specimen, a plot of shear stress and specimen thickness change versus shear displacement.

9.8. Plot of nominal shear stress versus percent shear (lateral) displacement.

9.9. Plots of log of time or square root of time versus deformation of those load increments where t_{50} was determined in the time-to-failure calculations.

9.10. Final degree of saturation, final moisture content, final wet density (unit weight), final dry density (unit weight).

9.11. Departure from the procedure outlined, such as special loading sequences or special wetting requirements.

10. KEYWORDS

10.1. Consolidated strength; direct shear; remolded strength; shear strength.

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[1] Similar except for SI units, but not technically identical to ASTM D3080-72(2003).
[2] See Section 5.4 for specimen/particle-size relationship.
[3] Section 6.3 includes guides for determining rate.
[4] See T 216, One-Dimensional Consolidation Properties of Soils.